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# The Relation of Woolly Apple Aphis to Per- ennial Canker Infec- tion with Other Notes on the Disease



Agricultural Experiment Station  
Oregon State Agricultural College  
CORVALLIS

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## SUMMARY

Studies of perennial canker conducted in the Hood River Valley of Oregon from 1925 to 1928 inclusive have brought out the following facts:

1. Perennial canker is shown to be a wound parasite apparently incapable of entering sound, uninjured tissue.

2. The canker is not truly perennial. New annual infections extend the cankers when conditions are favorable. Since conditions for this advance are usually favorable in the regions where the disease is serious, the disease in this sense is in effect perennial.

3. The woolly aphid is definitely associated with canker infection. Pruning wounds and canker calluses on which aphid was known not to have fed failed to develop a single infection. Where the aphid developed, on the other hand, approximately 90 percent canker infection followed.

4. Canker infection usually follows severe late aphid infestations. The degree of predisposition to canker infection resulting from early aphid attack or attacks by aphid in small numbers is not entirely known. Infection has sometimes followed early infestation of relatively short duration; sometimes it has not.

5. Extent of canker advance is to a large degree governed by winter temperatures. Infection which followed aphid attack during winters with a minimum of 6° and 20° F. has been superficial. Noticeable advance has occurred at temperatures ranging from -2° to -27° F., severity increasing with the drop in temperature.

6. Aphid galls check and crack to a slight degree during the summer and during mild winters. At temperatures below zero Fahrenheit the galls usually rupture and collapse on thawing. In this condition the callus apparently permits the entrance, followed by extensive advance, of the canker organism.

7. Pruning wounds, made in the winter, during certain years have been followed by infection. Little or no infection has occurred in pruning cuts made after the middle of February. Callus growth seems to be more vigorous in the case of spring pruning than on cuts made during early winter.

8. All pruning wounds are potential canker centers, as practically all are eventually attacked by woolly aphid. Cutting to stubs on the main framework of the tree is recommended as a means of preventing rapid advance by canker infections.

9. Various sprays on canker-bearing trees have thus far proved equally ineffective for the control of either aphid or perennial canker. Bordeaux mixture applied at different times in the year has not checked canker growth. Nicotine sulfate in five applications failed to prevent aphid from feeding on callus margins of untreated cankers.

10. Control of woolly aphid and perennial canker in the main framework of the trees, through the use of surgery, wound painting, and spraying, is recommended.

11. Susceptibility to perennial canker varies with different apple varieties. The leading commercial sorts in the Hood River Valley, Newtown, Ortley, and Spitzenburg are highly susceptible. Red sports of Delicious are recommended for planting owing to the fact that this variety shows much more immunity to the disease than other sorts adaptable to this district.

12. Trees of the Northern Spy variety are usually free from canker attack. It has not been determined whether this is due to immunity to the disease or to the fact that the variety is not subject to aphid attack. Such varieties as the Lady Apple, Transcendent Crab, Arkansas Black, and Black Twig, are readily attacked by the aphid but the disease usually fails to make serious advance into the bark.

13. The perennial canker fungus produces the "Bull's-eye rot" disease in stored fruit. Early picking and the use of bordeaux mixture in the last codling-moth spray are recommended, having been found effective in reducing attack on the fruit.

# The Relation of Woolly Apple Aphis to Perennial Canker Infection with Other Notes on the Disease

By

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Perennial canker<sup>1</sup> is the most serious and wide-spread disease affecting apple trees in the Hood River and adjacent valleys at the present time. Prior to 1919 the disease was more or less localized. Following the severe winter of 1919-20, when a minimum temperature of -27° F. was registered, much damage and weakening of trees resulted, causing the fungus to spread throughout the district to an alarming degree. Severe winter temperatures also occurred during the years 1924 and 1926, a condition which undoubtedly assisted in the progress the disease has made.

At the time the organism was described it was believed, from the character and appearance of the cankers, that the disease made annual extensions into surrounding healthy tissue as a result of its own activity. Thus the common name "perennial canker" was employed to distinguish the disease. Observations made during the past four years, however, point out the fact that the disease is very decidedly a wound parasite, and is apparently incapable of making advance into sound tissue unless assisted by other agencies. The disease is, therefore, not perennial but rather annual, though usually where infection has once become established in the form of a canker conditions are more often favorable to further advancement of the disease than a hindrance to it. During a number of years perennial cankers were tied upon healthy apple limbs as shown in Fig. 1: A. All such attempts to infect sound, unbroken tissue artificially have been unsuccessful.

Anthraxose cankers, tied upon limbs in the same way, readily led to attack upon healthy wood as shown in Fig. 1: B. The anthracnose fungus closely resembles the fungus causing perennial canker with which it was long confused. The woolly apple aphid<sup>2</sup> has been found to be definitely associated not only with new infection but also with reinfection of the established cankers.<sup>4, 5</sup> The severity of this infection, and the extent of advance the disease makes into tree tissue, is further governed by winter temperatures. Pruning of the trees during the inactive growth period has also been found to permit infection.

<sup>1</sup>*Gloeosporium perennans*. Zeller and Childs, Ore. Agr. Exp. Sta. Bul. 217. 1925.

<sup>2</sup>*Eriosoma lanigerum* (Hausmann).

<sup>4</sup>Perennial canker of apples, Leroy Childs, Ore. State Hort. Soc. 19th Annual Report, 1927.

<sup>5</sup>Perennial canker gains foothold in Okanagan, H. R. McLarty, Farm & Home, Feb. 1929. (This popular article came to the attention of the author at the time this bulletin was being written. In all essential details, Mr. McLarty's findings are in accordance with findings presented in this publication.)

## WOOLLY APHIS AND INFECTION

Following the discovery of the organism by Zeller and Childs<sup>2</sup> in 1925 it became necessary, before practical means of control could be intelligently undertaken, to determine first in what manner natural infection occurred on the trees.

A survey of the situation was made in the spring and early summer of 1925, at which time a large number of cankers and pruning wounds were



Fig. 1. Perennial canker does not attack sound tissue.

- (A) No infection below perennial canker tied upon tree.  
 (B) Numerous infections below anthracnose canker. Canker tied upon same tree for one year before photographing.

pruning wounds, untreated, and treated in various ways, was made the object of study. For this work orchards were chosen in which perennial canker was prevalent but which were to a large extent free from anthracnose, in order that conclusions might be arrived at without confusing the two diseases. The observations and tests were carried on in a way as

examined. Practically 100 percent of the pruning wounds, which had developed a good callus (Fig. 8: A) and upon which there was no evidence of woolly aphis infestation—present or past—were found to be free from infection. On the other hand, all infected calluses invariably showed the characteristic, knotted evidences of previous aphis infestation. Numerous cankers of long standing were examined. With few exceptions each callus—the wood structure beneath which only remained—showed, from the knotty condition, that each one of these in turn, had been infested with the aphis (Fig. 3: 1, a).

As a result of this strong evidence pointing to the relationship of the aphis to infection, a large series of cankers and

<sup>2</sup>Zeller, S. M., and Leroy Childs. Perennial canker of the apple. Ore. Agr. Exp. Sta. Bul. 217. 1925.

nearly typical of normal field conditions as it was possible to conduct them. Aphis infestation was allowed to take place naturally. All objects chosen for study were tagged and numbered (Fig. 4). Early in the work an attempt was made to establish aphis colonies artificially on certain calluses. This was not successful. During 1925 in some of the tests aphis infestations were not sufficient to permit the drawing of definite conclusions.



Fig. 2. Control of canker in this area will save the tree; this can be accomplished by following methods outlined in this publication.

The insects, however, were very numerous the next year. In 1926 the aphid-free controls were maintained with difficulty throughout the season. This was accomplished in one set of tests by the use of nicotine sulfate applied with a paint-brush at rather close intervals.



Fig. 3. I. Canker and heart-rot following winter injury.

- (A) Knotted woody callus growth evidence of previous aphid activity.  
 (B) and (C). Fruiting bodies of two heart-rot organisms of which there are several following canker infection.

II. Advance of the disease has been stopped by surgery and painting.  
 Tree badly diseased though still fruitful.

Observations concerning the influence of the aphid were outlined under three general headings: (1) Sound pruning-wound calluses observed with and without aphid. (2) Cankers cut out to healthy wood, resulting calluses observed with and without aphid. (3) Cankers untreated, dead tissue allowed to persist, observed with and without aphid (Table II). The work was further divided in that a series of wound dressings and paints was applied to the calluses found under these headings. Each subject was tagged and numbered.

## OBSERVATIONS FOR THE YEAR 1925-26

Most of the tests were started during the early summer of 1925, and observations were concluded, as reported here, in the early summer of 1927. Results of tests made during 1927 and 1928 have substantiated these earlier findings. Owing to the fact that woolly aphis behavior is quite erratic, it was found necessary to make numerous examinations at rather close intervals throughout the period of this investigation so that a complete record of the callus condition might be obtained. Owing to the fact that complete control can not be maintained in field tests of this sort, it is recognized that entire accuracy in the records was impossible. It is believed, however that experimental error is not large owing to the close watch that was maintained relative to the insects' activities. Unavoidable errors in the records in a few instances resulted from the undiscovered establishment of unexposed aphis colonies, located under overhanging bark and under healing callus tissue. Certain paints on drying were found not only to offer protective coverings for the aphis but also to make it impossible accurately to record existing infestations at all times. After infection had been found at places where external inspections had revealed no aphis, protective coverings were removed and usually tell-tale evidence of previous aphis attack could be found. Occasionally infection occurred which could not be definitely associated with the insects. The writer strongly believes that such infections were probably associated with aphis infestation although the presence of the insects was not noted. Where the aphis colonies were small, their location on the calluses was indicated with colored crayon marks in order that the condition of these particular areas might be observed at later dates (Fig. 5).

The winter following the establishment of the tests proved to be exceptionally mild. The minimum temperature recorded for the entire year was 20° F. That this is unusual may be judged from the fact that only twice in the past eight years, 1925-26 and 1927-28, has zero not been reached in the Hood River area. In many parts of the district the woolly aphis infestation was much less than usual; many cankers and calluses remained entirely free from these insects throughout the summer and fall of 1925. As a result of these conditions practically no new infection of a serious nature was found to have taken place. Healthy calluses were found in the cankers and on the pruning wounds in most orchards throughout the Valley in the spring of 1926. Frequent examination of callus tissue made during the winter failed to show discoloration or any other evidence of infection on aphis-free calluses. In late winter some of the aphis-infested spots became darker-colored than adjacent, non-infested tissue. This killing back, in practically all cases noted, was superficial in character, and usually no subsequent evidence appeared on these spots.

As already noted, aphis infestation during 1925 failed to develop to its usual extent. Less than 35 percent of the untreated calluses under observation developed aphis infestation and often upon many of these the colonies were small or the period of attack short. Where the aphis colonies were scattered on the calluses their location was indicated by blue pencil marks. Where infestation was complete, the condition was recorded as such.

Table I summarizes the observations made relative to the influence aphis exerts on bringing about infestation. Infection that developed during

TABLE I. RELATION OF WOOLLY APHIS TO PERENNIAL CANKER  
Infection on Newtown apple trees

First-year observations made during the summer of 1926 on untreated calluses of various types selected in the summer of 1925. The winter of 1925-26 was mild.

Character of callus under observation	Number of calluses	Calluses with no aphis found present during 1925			Calluses with aphis found present during 1925			Percentage of all calluses becoming infested	Character of infection
		Number observed	Developing of canker	Percentage of canker infection	Number observed	Developing of canker	Percentage of canker infection		
				%			%	%	
Sound pruning wounds. No aphis previous to 1925.	138	102*	0	0	36	24	66.6	17.3	Confined for most part to callus. Spots at aphid colonies. Infection failed to spread.
Cankers with dead tissue removed (Aug. 1925) exposing new callus.	73	35†	0	0	38	13	34.2	17.8	Infection for most part confined to callus. In one case disease extended back for $\frac{1}{2}$ inch.
Dead canker tissue not removed from callus growing beneath.	95	51	0	0	44	36	81.8	37.7	Infection often involving entire callus. Penetration, however, slight.
Cankers cut out in July, 1925. No further treatment.	54	47	0	0	7	2	28.5	3.7	Spots at aphid colonies.
Total	360	235	0	0	125‡	75	60.0	20.8	

\*Aphis kept off 39 of these by applications of Black Leaf.

†Aphis kept off by regular applications of Black Leaf.

‡Aphis infestation in many cases light during 1925. All aphid recorded regardless of numbers or extent of activity.

TABLE II. RELATION OF WOOLLY APHIS TO PERENNIAL CANKER INFECTION ON NEWTOWN APPLE TREES  
Second-year observations completed in early summer of 1927 on untreated calluses referred to in Table I. The winter of 1926-27 was severe.

Character of callus under observation	Calluses with no aphis found during 1926			Calluses with aphis found present during 1926			Character of infection
	Number observed	Developing canker	Percentage of canker infection	Number observed	Developing canker	Percentage of canker infection	
			%			%	
Sound pruning wounds. No aphis previous to 1925.	64	3	8.1	27	19	70.3	Usually severe. Complete where aphs were numerous. Spots where small aphs colonies occurred.
Cankers cut out Aug. 1925. No further treatment.	54	3	27.2	43	39	90.6	Usually severe. Complete where aphs were numerous. Spots where small aphs colonies occurred.
Cankers with dead tissue adhering.	53	0	0	51	50	98.02	
Aphis-free check. Calluses painted at intervals with Black Leaf.	24	0	0	----	----	-----	Calluses all remained perfectly sound without sign of infection.
Totals	195	6	8.1	121	108	89.2	

the winter of 1925-26 was insignificant compared to usual performance. Three hundred and sixty untreated calluses of various sorts were under continual observation. Aphis had developed in varying degree upon 125 of these during the summer of 1925. On some of these callus margins living aphids were found late into December owing to the mildness of the winter. Examinations made from time to time during the winter indicated that some discoloration of the callus tissue was taking place at points where aphid colonies had been located; a green, healthy condition prevailed on calluses where there had been no aphids.

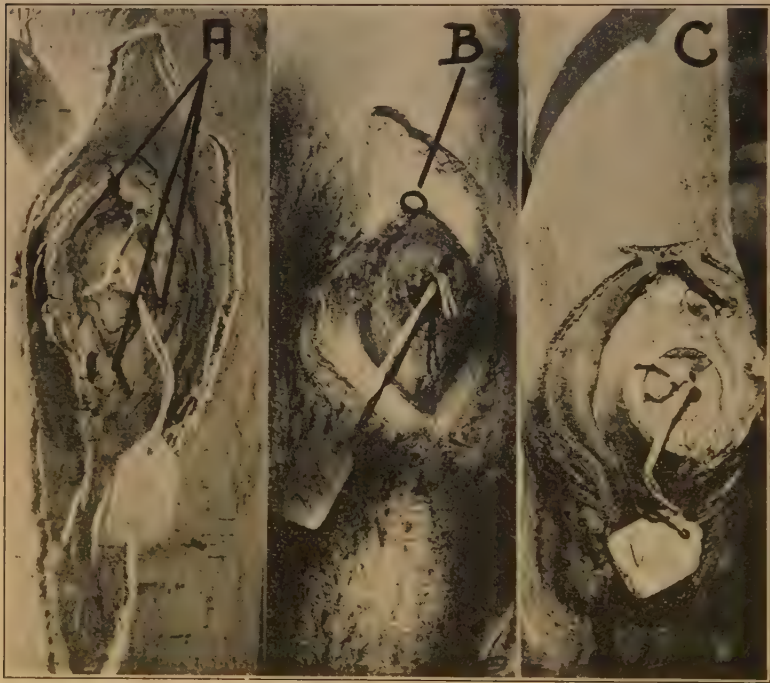


Fig. 4. Relation of woolly aphis to infection.

- (A) Painted callus on which paint dried and lifted, thus sheltering aphids. Serious canker infection always followed such aphid attack.
- (B) Untreated callus on which a small colony of aphids fed during 1926; infection (removed) followed at this spot later; remainder of callus sound.
- (C) Untreated aphid-free callus free from canker infection. Subjects A, B, C on same tree located within three feet of each other.

During June, 1926, a final check of conditions was made. Not a single infected spot was found on the 235 aphid-free calluses, whereas 75, or 60 percent, of aphid-infested calluses showed infection of usually slight extent. Probably owing to the mild winter (the winter of 1927-28 was also mild with same type of infection developing) infection was very superficial in character. In 1926 the canker organism was recovered by S. M. Zeller from several of these shallow, dead areas. The developing lesions were in practically all cases confined to the callus; a few, however, (approximately

4 percent) extended into the cambium and bark tissues, later developing typical characteristics with fruiting bodies of the organism. The infections were always associated with aphid colonies. In many cases, where the insects occurred early in the summer only, or where but few young insects were recorded, no infection developed.

TABLE III. RELATION OF WOOLLY APHIS TO CANCER INFECTION

First-year results of painting tests. Calluses prepared and painted July, 1925; condition recorded June, 1926. See also Tables IV and V.

Experiment No. and material	Calluses under obser- vation	Calluses, no aphis 1925	Percentage of aphis- free calluses de- veloping canker	Calluses with aphis 1925	Percentage of calluses with aphis developing canker 1926
			%		%
A. Coal tar.....	62	61	0	1	0
B. Hood River tree paint .....	58	57	0	1	0
C. Acme roof paint .....	55	51	0	4	0
D. S. W. No. 1.....	61	59	0	2	0
E. S. W. No. 2.....	60	60	0	0	0
F. S. W. No. 3.....	59	58	0	1	0
G. Fungi-Bord. oil	55	55	0	0	0
H. White lead and oil .....	65	65	0	0	0
I. Mt. Hood tree paint .....	65	65	0	0	0
K. Bordo-Mix .....	57	57	0	0	0
Check, untreated..	172	161	0	11	18.1*
Aphis-free Check calluses painted at intervals with B. L. 40....	24	24	0	0	0
Totals .....	793	773	0	20	10.0

\*Two aphis-infested calluses found to have shallow spots on margins of callus.

In the test where the dead, fungus-containing bark was not removed from the cankers, aphis infestation became severe (see Fig. 6: B). In this series, because of the extensive, almost complete infestation of the callus by these insects, infection involved most of the callus. With the exception of one case, however, where infection spread well into the bark area, all were superficial. Fifty-one of the ninety-five cankers of this character remained free from the insects during 1925. No infestation developed on these though in many instances the fungus was fruiting abundantly for several weeks immediately above the cankered area.

## OBSERVATIONS FOR THE YEAR 1926-27

The same untreated, tagged calluses used in 1925 were kept under observation throughout the year 1926. Examination was made at regular intervals. Facts of importance were recorded, particularly as related to the presence of the woolly aphid and the influence of these insects on the callus. Location of colonies was again indicated by colored crayon marks on adjacent bark. During the year, 172 untreated calluses of various sorts were under observation. There were also 24 calluses (pruning wound and

healthy margins of scars which were originally cankers) regularly painted with Black Leaf 40 to insure their freedom from aphid throughout the year.

Temperature conditions occurring during the winter of 1926-27 proved to be quite the reverse of those of the preceding year. During both December and January sub-zero temperatures were recorded; a minimum of  $-15^{\circ}$  F. being registered in late January. Fifty of the 172 untreated calluses remained aphid-free so far as outward appearances were concerned. Six of these, or 12 percent, however, developed perennial canker infection. The



Fig. 5.

- (A) Line points to location of aphid colony. Infection followed later. Dotted line points to location of small aphid colonies with canker, which less infection. Callus not yet free from aphid attack—no infection.
- (B) Line points to location of aphid-infested callus following freezing. Canker invariably follows such a condition. Dotted line points to hollow aphid gall, collapsed as a result of freezing. Photographed a few weeks after occurrence of freezing temperatures.

parallel set of calluses kept free from aphid as a result of Black Leaf applications failed to develop a single infection. One hundred and twenty-one of the check calluses supported colonies of aphid at some time during the year; 108, or 89.2 percent, developed infection.

TABLE IV. RELATION OF WOOLLY APHIS TO CANKER INFECTION

Second-year results on calluses prepared and painted July, 1925. No treatment in 1926. Condition as recorded observed in June, 1927. See Table III for first-year results.

Painted 1925. No further treatment	Calluses under observation	Calluses with no aphid present during year			Calluses with aphid present during year		
		Number observed	Developing canker	Percent- age of canker infection	Number observed	Developing canker	Percent- age of canker infection
A. Coal tar .....	32	6	0	0	26	26	100.0
B. Hood River tree paint .....	31	3	0	0	28	22	78.6
C. Acme roof paint .....	31	13	0	0	18	16	88.8
D. S. W. No. 1..	27	9	0	0	18	18	100.0
E. S. W. No. 2..	33	5	1	20.0	28	27	96.4
F. S. W. No. 3..	34	4	2	50.0	30	28	93.4
G. Fungi-Bor- do and oil.....	40	4	0	0	36	35	97.2
H. White lead and oil .....	40	8	1	12.5	32	29	90.6
I. Mt. Hood tree paint .....	29	6	0	0	23	19	82.6
K. Bord. Mix..	28	6	0	0	22	22	100.0
Check. No treatment .....	172	51	7	13.7	121	108	89.2
Check Black Leaf for complete prevention of aphid .....	24	24	0	0	---	---	---
Totals .....	521	139	11	7.9	382	350	91.6

Usually size and severity of the resulting infection was in proportion to the severity of aphid infestation. In all cases where heavy infestation was recorded, the disease made extensive advances into the surrounding area (Fig. 4: A). Where the aphid colonies were irregular in their occurrence or where the colonies were localized on the callus, infection followed only at the points of attack (Fig. 4: B). Infection seemed to follow more completely in the case of late infestation on the part of the insects than for early infestation. Early aphid attack of relatively short duration, however, was occasionally found to predispose the callus to infection. A study is now being made to determine many important points relative to the time of aphid attack and the relation of this attack to canker infection.

As in the case of the first-year observations, experimental error is probably responsible for infection being present on calluses recorded as aphid-free. It seems probable that the insects were either present for a relatively short period of time between observation dates or that they were overlooked when the calluses were being examined. Cutting into or disturbing the calluses in any way was always avoided in these tests in order that there might not be added other factors which might have a bearing upon the introduction of infection.

## TEMPERATURE AND INFECTION

Although data now available are too limited to permit the drawing of definite conclusions, it seems more than probable that factors of winter temperature and resulting freezing play an important part, along with the aphid, in determining the extent of canker advance into the healthy bark. Table VIII summarizes minimum winter temperature records in the Hood River district for the past ten years. No record of the relation of aphid to infection was recorded until the winter of 1923-24. Moderate temperature has occurred during three winters of this period; 1920-21, 1925-26, and 1927-28. Unfortunately no written record was made relative to canker growths during the winter of 1920-21. As the writer now recalls, the year was one during which callus growth was good and accompanied by little killing back of the character that prevailed during the preceding year. Examination of many old cankers of the type shown in Fig. 7 substantiates this opinion. Very slight infection advances occurred during the other two mild winters. These infections seldom extended deeper than the callus itself and were always confined to points of aphid attack.

The extent to which aphid-infested (galled) calluses split or check has depended upon the severity of temperature that followed. During years of mild temperature, checking of the galls to a certain extent has been observed to take place at points where aphids have fed. This condition can often be observed on severely infested water sprouts, before the occurrence of frost in the fall, and is a condition that doubtless permits infection to take place, though it may be superficial in character, when not associated with cold winter temperatures. Though the fungus has been found west of the Cascade Mountains, the usually mild winter temperatures prevailing in Western and Southern Oregon are probably responsible for conditions which prevent the disease from making serious advance.

Observations made during the past ten years indicate that the extent of canker advance into apple tissue increases with the lowering of temperature. The most extensive advance occurred in the winter of 1919-20, when a minimum of  $-27^{\circ}$  F. occurred in the Lower Hood River Valley. During that winter, temperatures were higher in the upper elevations of the Valley with correspondingly less damage. In the winter of 1926-27 conditions were reversed. A temperature of  $-11^{\circ}$  occurred in the Lower Valley and  $-17^{\circ}$  in the Upper Valley; the extent of the disease was noticeably greater in areas where the lower temperature prevailed. The precise temperature required to bring about tissue injury to such an extent that infection of a serious character takes place has not been determined. This appears, however, to be approximately zero F. Noticeable infection has occurred during years when the lowest winter temperature registered  $-2^{\circ}$  and  $-4^{\circ}$ ; slight superficial infection at  $+6^{\circ}$ , and only a trace when the lowest winter temperature recorded was  $+20^{\circ}$ .

## EFFECT OF FREEZING ON APHID GALLS

Callus growth of various types, both aphid-infested and aphid-free, was examined during the winter of 1925-26. At the time of coldest weather ( $+20^{\circ}$  F.) no sign of ice-formation was observed in the cell structure of the galled callus tissue or in the healthy or normal callus tissue. No severe rupturing of the bark took place during the winter, though slight checking of the bark on aphid galls was observed. This condition was noted again

during the mild winter of 1927-28. Water sprouts, severely infested with aphids, checked noticeably, infection following later. As previously stated resulting perennial canker infection was for the most part superficial in character, this infection appearing as dead spots on some of the calluses previously attacked by the aphids.

TABLE V. RELATION OF WOOLLY APHIS TO CANKER INFECTION

Second-year results on callus prepared and painted in July, 1925, and repainted in July, 1926. Condition as recorded observed in June, 1927. See Table III for first-year results.

Tests of 1925. Calluses repainted July, 1926.	Calluses under observation	Calluses with no aphids found present during year			Calluses with aphids found present during year		
		Number observed	Developing canker	Percentage of canker infection	Number observed	Developing canker	Percentage of canker infection
				%			%
A. Coal tar....	24	8	1	12.5	16	6	37.5
B. Hood River tree paint ..	24	3	0	0	21	3	12.5
C. Acme roof paint .....	21	6	1	16.6	15	11	73.3
D. S.W. No. 1	53	18	3	16.6	35	33	94.2
E. S.W. No. 2	22	10	8*	80.0	12	12	100.0
F. S.W. No. 3	24	7	0	0	17	15	88.2
G. Fungi-Bordeaux and oil†	15	2	0	0	13	13	100.0
H. White lead and oil .....	25	3	0	0	22	11	50.0
I. Mt. Hood tree paint‡	25	5	0	0	20	14	70.0
K. Bordeaux mix‡	29	5	3	60.0	24	24	100.0
Check. No treatment ..	172	51	7	13.7	121	108	89.2
Check. Black Leaf for complete prevention of aphids .....	24	24	0	0	-----	-----	-----
Totals .....	458	142	23	16.15	316	250	79.1

\*Paint injury present; probably associated with canker increase.

†Not repainted until November, 1926.

‡Furfural substituted for bordeaux mixture.

Observations of a similar character were continued during the winter of 1926-27. Following the temperature of  $-5^{\circ}$  F., December 14, much discoloration was noted in the cambium tissue. By January 10, the margins of many aphid-infested calluses had reached a color ranging from brown to nearly black. Further observations were made on January 22, at which time the temperature dropped to  $-11^{\circ}$  F. Frozen calluses of various sorts, previously infested and non-infested, were collected in the orchard and brought to the laboratory. These were found to be solidly frozen. The gall-like structures, formed by the aphids, were found to be filled with ice, which on thawing left large irregular cavities. The thawing-out process was further observed under the binocular microscope. With the warming of the tissue, ruptures took place on the surface of the aphid-infested calluses (Fig. 5: B) followed later by a complete collapse of the internal

structure of the enlarged tissue. This rupturing did not occur on sound calluses or in parts of callus uninfested with the aphid (Fig. 5: A).

Extensive discoloration soon followed injury of this character. It has not been determined whether infection takes place immediately following

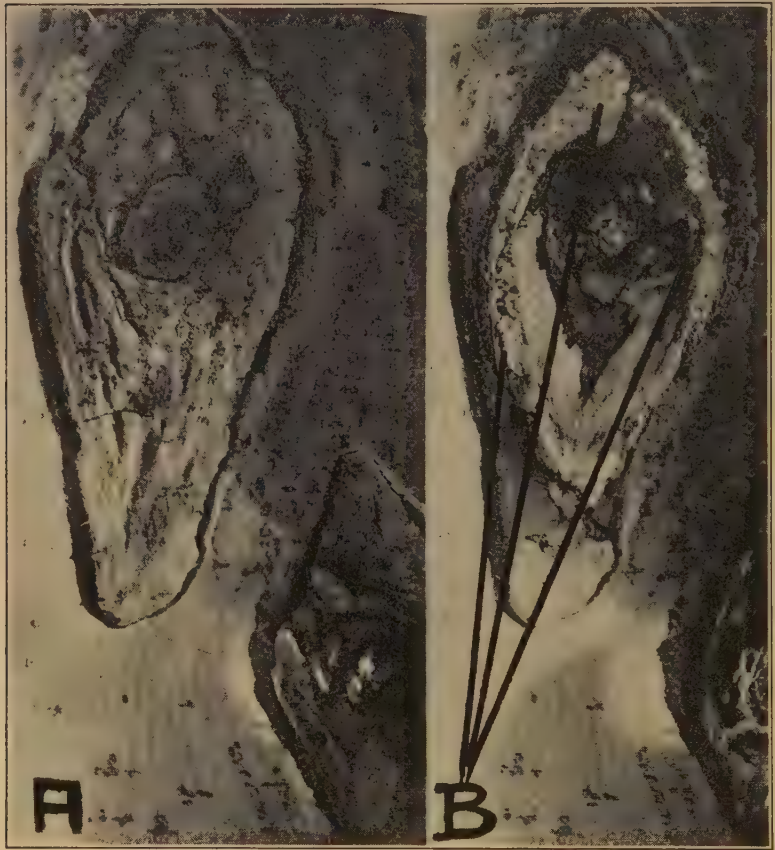


Fig. 6.

- (A) Two-year-old canker. Note apparent absence of aphids.  
(B) Dead bark removed showing new callus completely covered with woolly aphids. These insects were completely protected from their natural enemies and from sprays that might be applied for aphid control.

this injury or whether it is delayed. Gradual increase in the size and intensity of the discolored area about the callus seems to point to the fact that infection occurs shortly after mechanical injury has taken place. Subsequent observations have shown that freezing of the galls is a very important feature associated with aphid activity in the bringing about of canker infection.

## THE EFFECTS OF PAINTS ON APHIS CONTROL

A number of paints and wound dressings were tested during 1925 and 1926 to determine not only their influence as factors in the control of the disease but their relationship to aphis infestation as well. These included the following materials: commercial coal tar; Hood River tree paint (a paint containing rosin, fish oil, and bluestone); Acme roof paint; three grades of Sherwin Williams tree paint known as canker paint Numbers 1, 2, and 3; a mixture of Fungi-Bordo and raw linseed-oil; white lead and raw linseed-oil; Mt. Hood tree paint (something of the character of the Hood River paint); bordeaux mixture and furfural. As has already been discussed, the year 1925 was not favorable to the development of the aphis nor were temperatures sufficiently cold to freeze the tissues surrounding the calluses. Very slight aphis infestation occurred in the paint tests, with the result that no comparisons could be made on account of the lack of subsequent infection. Table III summarizes the observations made during the summer of 1925 and the winter following into 1926. No infection or injury occurred on the painted calluses.

During 1926 and 1927 observations were continued employing the same calluses and paints that had been used the preceding year. The same untreated controls were employed, while in the case of the painted calluses half of those in each series were repainted in July, 1926. The remaining half received no further paint.

As a result of the relationship of the woolly aphis to canker infection, the most important problem becomes that of woolly aphis control. The findings in these tests indicate that as fungicidal agents wound dressings or canker paints are of secondary importance though there appears to be some possibility that some material might be found which would prevent infection from taking place, even on susceptible aphis-galled callus tissue. Our results obtained with the Hood River tree paint and another paint of somewhat similar physical character indicate that some benefits are to be derived from fungicidal action of this sort.

At the time the tests were started, paints were chosen at random. At best, the available supply was limited and their reactions to the tree tissues were little known. Paints, from the standpoint of woolly aphis control, act in at least two ways: as a mechanical barrier or as a repellent to the insects. With a fungicide added, paints may act also as a mechanical barrier to inroads of the fungus organism and as an agent destructive to spores and growth of the fungus. The precise effects of the character indicated have not been determined for the paints used in these tests except in a general way as indicated by final results.

Table VI presents data showing the effect of the various paints used on the amount of aphis infestation and subsequent development of canker. The paints were first applied to the calluses in July, 1925. Practically no aphis infestation developed in the orchard where the painting tests were being made during that year. In 1926 each experiment was divided in two; one half of the calluses were repainted and the other half received no further treatment. Aphis conditions were checked up at close intervals throughout the year. At the end of the season it was possible to draw several important conclusions. Unpainted calluses of various sorts developed 70.3 percent aphis infestation during 1926. This was found to be somewhat lower than the average infestation occurring on painted calluses

that were given no further attention the year following treatment, where 81.1 percent infestation occurred. Callus growth was found usually to lift or separate the paint from the wood to such an extent that it became a harboring place for the insects (Fig. 4: A), whereas the unpainted, smooth, exposed callus proved to be less attractive to the aphids. None of the paints used was entirely effective as an aphid-barrier for the year July 1925 to July 1926. By July, 1926, the percentage of aphid infestation on the painted wounds was greater in most cases than on the untreated checks. Repainting of aphid-infested calluses at that time definitely checked reinfestation during the remainder of the year. In the case of the Hood River tree paint reinfestation of 4.15 percent occurred; coal tar 8.1; Acme roof paint 10.5; Sherwin Williams No. 3, 25.0; white lead and oil 26.2. The remainder of the materials used were not applied until November, at which time aphid activity had largely ceased.

TABLE VI. EFFECT OF PAINTS ON APHIS CONTROL AND CANKER DEVELOPMENT

Painted wounds when neglected harbor more aphids than those untreated. Observations started July, 1925. Results determined, November, 1926.

Experiment number, materials used	Check calluses, no treatment, percentage of aphid infestation	Painted July, 1925, no treatment 1926. Percentage of aphid infestation	Painted July, 1925. Repainted July, 1926		Percentage of canker infection present. Repaint series
			Percentage aphid before repainting	Percentage aphid* infestation	
A. Coal tar.....	62.4	81.2	66.6	8.3	29.1
B. Hood River tree paint .....	76.6	90.2	87.4	4.15	12.5
C. Acme roof paint .....	79.0	58.0	71.4	10.5	57.1
F. S. W. No. 3.....	68.7	88.2	70.8	25.0	62.5
H. White lead and oil .....	50.0	80.0	88.0	26.2	44.0
G. Fungi bordeaux and oil .....	66.3	90.0	86.6	.....†	86.6
I. Mt. Hood tree paint .....	86.6	87.8	80.0	.....†	56.0
K. Bordeaux painted‡ .....	55.2	71.4	85.6	.....†	65.5
Untreated check .....	70.3	81.1	.....	.....	65.5

\*Percentage aphid developing between July and November.

†Repainted in November, 1926.

‡Furfural substituted for bordeaux in November, 1926.

In these tests the Hood River tree paint gave the best results from the standpoint not only of aphid control but of control of the cankers as well. This paint adhered closely to the callus and was found sufficiently pliable to expand for some time, with the callus growth acting during this period as a definite barrier to the aphids. Further observations will probably show variability in the period of effectiveness of the material depending upon such conditions as whether applications are made during the period of greatest callus activity, vigor and age of tree, and degree of aphid infestation.

In order to get maximum protection it is not thought advisable to make applications before July. To what extent the aphids feeding before

July predispose calluses to infection is not entirely known. Canker infection has been observed to follow early aphid infestation though as a rule the disease does not make the same serious type of advance as in calluses where the aphids are numerous late in the season. Tests have shown that the Hood River tree paint and paints of similar character have prevented canker infection from taking place regardless of the fact that before painting was done aphids had fed upon the calluses as late as July 15. With an aphid infestation of 87.4 percent, painting at that time held subsequent



Fig. 7. The rings of woody growth around this pruning wound indicate the extent to which the tree tried to overcome canker attack. Diseased bark has been removed.

canker development down to 12.5 percent. Further investigations are under way with reference to the use of paints in aphid control and the relation of this control to canker development.

The results of the investigation show that paints that dry with a crust-like coating over the callus offer, during the growing season, relatively short protection (Fig. 8: A). The growing callus soon lifts this material away from the wood and underneath it the aphids find ideal quarters. The Fungi-Bordo-oil combination and the three types of Sherwin Williams paints were inclined to dry out rapidly, leaving a shelllike covering for the aphids under which they soon established themselves.

## RELATION OF PRUNING TO INFECTION

Evidence gathered from time to time since 1924 has pointed to the fact that pruning, particularly that employed during the period of greatest dormancy (December to mid-February) has had a tendency to induce infection. Pruning tests were started in December, 1926, and continued by monthly pruning of the trees until approximately bloom time. This experiment has been kept going and this year (1929) pruning is being done at fifteen-day intervals on both pears and apples for the purpose of recording reactions to these practices in the form not only of tree response but of canker infection as well.

The results obtained from the pruning tests carried on during the winter of 1926-27 are recorded in Table VII. Two mature Newtown trees were used in each test. Both possessed numerous cankers containing the disease organism. Methods employed were similar to those used in commercial practice and results were tabulated from cuts made in all parts of the trees. Responses in the way of callus growth, dying back of tissue at point of cutting, and positive infection were recorded during the following summer. Establishment of positive infection was based upon the fruiting of the organism. It was not determined whether the slight rings often showing about the pruning wounds contained the fungus organism. No advance of the disease followed such injury where aphid infestation did not take place. Winter conditions, as has been stated, were rather severe; a temperature of  $-5^{\circ}$  F. occurred on December 14 and  $-11^{\circ}$  on January 21, the date of the third pruning. Resulting development on cuts made at that time showed little difference from cuts made twenty-four and fifty days earlier.

TABLE VII. INFLUENCE ON CANKER INFECTION OF PRUNING  
THROUGHOUT WINTER 1926-27

No treatment							
Date of pruning	Number of cuts	Positive infection	Percentage of positive infection	Cuts with dead ring of tissue below		Percentage	Percentage of cuts with vigorous callus growth
				Noticeable	Slight		
			%			%	%
Dec. 3, 1926....	60	7	11.6	29	20	81.6	11.6
Dec. 29, 1926....	58	12	21.1	26	20	79.2	0
Jan. 21, 1926....	61	6	9.8	31	18	80.3	9.8
Feb. 3, 1927....	66	0	0	12	29	62.1	37.8
Mar. 3, 1927....	77	1	1.3	6	38	57.1	41.6
Mar. 20, 1927....	71	0	0	3	41	62.0	38.0
Pruned as above, painted with coal tar within a day							
Dec. 3, 1926....	25	4	16.0	---	---	72.0	12.0
Dec. 29, 1926....	20	6	30.0	14	0	70.0	0.0
Jan. 21, 1927....	25	6	25.0	1	17	72.0	8.0
Feb. 3, 1927....	23	6	26.2	5	12	73.9	0
Mar. 3, 1927....	14	2	14.2	6	6	85.7	0

Positive infection of a significant amount occurred in the December and January prunings—11.6 percent, 21.1 percent, and 9.8 percent respectively. No infections occurred on pruning wounds of February 3; one appeared on the March 3 cuttings and none on March 20. The per-

centage of vigorous callus growth was found to be noticeably better beginning with the February 3 pruning tests (see Table VII).

In the 1926-27 pruning tests coal tar paint was applied to cuts within a day after the cutting had been done. That the practice was injurious to callus growth and induced infection is shown in Table VII. Infection of an appreciable amount followed throughout the season. The paint apparently sealed in spores and maintained more uniform conditions for the growth of the fungus than occurred in the exposed cuts. The writer has successfully inoculated apple trees during April and May from pure culture when the inoculum was sealed in with paraffin, while no infection occurred on uncovered wounds to which the culture was applied. It appears questionable whether any paint should be applied immediately after the cut has been made. Paints applied immediately after cankers have been cut during mid-summer have caused injury. These should not be applied until the callus starts to grow.

Pruning tests were continued through the relatively mild winter of 1927-28. The first cutting was done on January 5 and pruning was continued at approximately fifteen-day intervals until May 18. Dying back below the cut surface was not as noticeable nor as extensive as had been



Fig. 8.

- (A) Aphis-free callus on pruning wound—no infection; compare with Fig. 5: B. Note how callus has grown away from paint in a year's time.
- (B) Aphis infestation on pruning wound; canker infection usually follows such an attack.

observed the previous year. Using the fruiting of the fungus as a basis for determining positive infection, not a single case was observed. Dying back was found to be much more conspicuous in the prunings of January and early February (40.0 percent, 38.9 percent, and 21.0 percent in the order of pruning) with a correspondingly less noticeable callus growth. Only traces of dead outer tissue were found after the middle of February with an average of more than 25 percent vigorous callus growth on the pruning wounds.

That canker infection can occur following winter pruning was demonstrated in these tests, though it does not al-

ways follow such a practice. It seems probable that such factors as temperature and rainfall following cutting play an important part in the establishment of infection. The 1926-27 results indicate that trees should not be pruned before mid-February. The practice of pruning after this date appears to be a relatively safe procedure as far as danger of immediate infection goes.

As a result of the relation of aphids to the spread of the disease, minimizing of pruning is felt to be desirable. Because of this insect's relationship to the disease, practically every pruning wound becomes a potential canker owing to the fact that woolly aphids, sooner or later, attacks at least 90 percent of the resulting callus growths. Until more is known about the disease the number of cuts made in each tree should be reduced to as few as possible; cutting to stubs, rather than cutting back to the main branch, is recommended, particularly along the scaffold branches. This practice delays the entrance of the disease into the more vital portions of the trees, owing to the fact the fungus usually makes slow progress in branches cut in this manner. The callus growth on cuts of this character is weak and not as attractive to the woolly aphids as the callus that occurs in close-cut pruning.

## RELATIVE SUSCEPTIBILITY OF VARIETIES

Of all apple varieties grown in the Hood River district, the Yellow Newtown is the most susceptible to canker infection, followed by Ortley and Spitzenburg. Winter Banana, Gravenstein, Arkansas Black, Black Twig, and Delicious are much less susceptible than the first group. Very slight infection occurs on such varieties as Northern Spy, Astrachan, Lady Apple and Transcendent Crab. Lack of susceptibility to aphid infestation, as in the Northern Spy, which is almost immune to aphid attacks, is perhaps

TABLE VIII. MINIMUM WINTER TEMPERATURES, HOOD RIVER, OREGON, 1919-20 TO 1928-29 AND RELATION TO EXTENT OF CANKER INFECTION

Winter	To Jan. 1 Degrees	After Jan. 1 Fahrenheit	Minimum for the season	Record of canker ad- vance about old infections	Infection on— Calluses with      Calluses aphis                      no aphis	
1919-20	-27	+17	-27	Severe	-----	-----
1920-21	+17	+17	+17	No positive record. (Probably slight or none)	-----	-----
1921-22	+11	-12 Jan.	-12	Positive— general	-----	-----
1922-23	-2	+5 Jan.	-2	Positive	-----	-----
1923-24	+14	-4 Jan.	-4	Positive	Severe	None
1924-25	-12	+24 Feb.	-12	Severe	Severe	None
1925-26	+20	+21	+20	Trace	Spots superficial at points of aphid attack	None
1926-27	-5	-11	-11	Severe	Severe	None
1927-28	+6	+6	+6	Slight	Spots superficial at points of aphid attack	None
1928-29	+20	-11	-11	General*	General*	None

\*Advance of the disease in many instances slight.

the factor bringing about apparent immunity to the disease rather than actual lack of susceptibility of the variety to the disease. On the other

hand, such varieties as the Black Twig, Lady Apple, Arkansas Black, are often severely infested with woolly aphis, but regardless of this fact the disease does not, as a rule, make serious extensions into the tissue of the trees, indicating in such cases, definite resistance.

Of the good standard sorts which are grown in the Hood River district the Delicious is the most resistant to canker advance. In a number of orchards during the past ten years the writer has had an opportunity to compare this variety with adjacent Newtown and Spitzenburg trees. In many instances the Delicious remains fruitful, possessing relatively few cankers of a serious character while the other two varieties have become badly damaged. Because of this greater tendency to resist-

ance the Delicious is recommended for replacements in badly cankered orchards. Either Starking or Richared, red sports of Delicious, should be planted.

### PERENNIAL CANKER INFECTION ON FRUIT

The perennial canker organism attacks the fruit and the resulting infection has been called "Bull's-eye Rot" by Fisher.<sup>6</sup> During the past few years this disease has very materially affected the condition of packed fruit with resulting loss to growers and shippers. Control measures for the prevention of this decay have been under study for several years at the Hood River Station and a complete report will be made at a later date.



Fig. 9.

- (A) Aphis infestation on painted callus neglected for a year. Annual repainting is necessary.
- (B) Scattered aphis colonies; infection will develop at these points as shown in Fig. 5: A.

<sup>6</sup>A New Apple Rot Disease, D. F. Fisher, Proc. Wash. State Hort. Soc. 1925.

Serious fruit infection is associated with late harvesting and rainy weather. Whether such infection actually takes place in the orchard or whether spores are merely lodged on the fruit, later to enter the apple through lenticels or points of injury, has not been determined. Little or no infection takes place upon early-picked fruit. Late-picked fruit during dry falls is relatively free from infection. The writer has found bordeaux mixture (4-4-50) applied with the last codling-moth spray in late August or September, to be of definite value in reducing infection. On bordeaux-sprayed fruit, arsenic removal is also more easily accomplished than where lead arsenate alone has been used, owing to the favorable reaction between the acid, washing bath, and lime in the bordeaux coating. On the other hand the use of bordeaux mixture late in the fall is inclined to induce "red

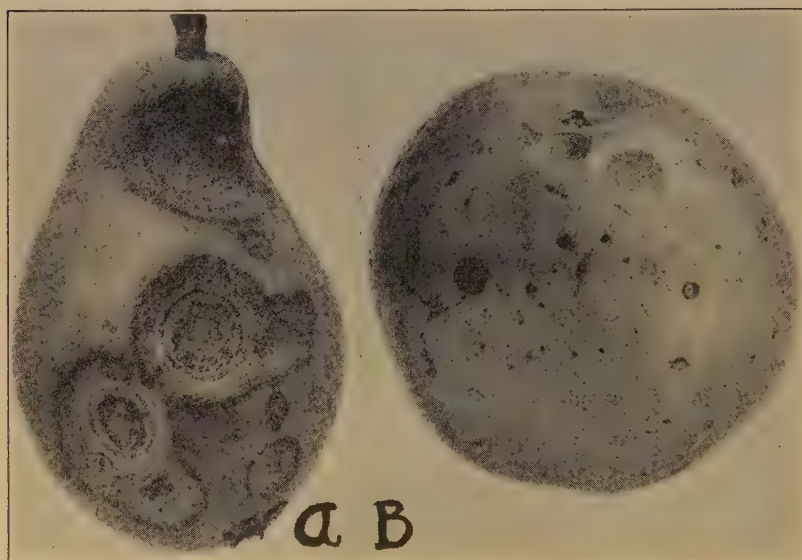


Fig. 10.

- (A) "Bull's-eye Rot" on Anjou pear due to the perennial canker fungus.  
 (B) Characteristic rot on apple. Perennial canker rarely attacks pear trees.

spot" at the lenticels, particularly on fruits exposed to the direct rays of the sun. Alternate periods of rain and sunshine increase this red spotting of fruit, especially on yellow varieties. Under these conditions red spotting takes place on unsprayed trees but usually not to the same extent. This damage can be prevented for the most part by harvesting fruit in proper season.

### CONTROL RECOMMENDATIONS

The practical application of the findings presented in this bulletin indicate that the problem of controlling perennial canker sufficiently to prevent infected trees from going into rapid decline, is not altogether hopeless. It is clear that unless given attention, it will be only a question of time until the disease, together with complications of heart-rot that follow,

will reduce trees in this district to a point where they will be no longer productive. The cost of applying suggested control measures is rather high, though not excessive. It is believed that this cost on the average will prove to be no greater than that of fighting the codling-moth or some of the other serious orchard difficulties.

None of the orchard sprays tested has thus far proved effective in preventing the advance of the disease. Bordeaux-mixture used alone or in combination in all practicable periods of tree development has given little or no benefit. To check the advance of this fungus at the present time growers must use other methods than those they have been employing.

The attack on the disease suggested here is built around the control of the woolly aphis, an insect which because of its habits is most difficult to subdue (Fig. 5). This insect feeds upon succulent, growing tissue, preferring, where available, tender tissue located under some sheltering cover. In these locations the insects are protected from their natural enemies, of which there are several capable of eliminating exposed colonies in a very short time. A canker, once established (Fig. 6), offers under its margins complete protection to the aphis from these predatory enemies and from contact sprays that might be used for their destruction. During 1928 an oil spray used in the spring followed by five applications of Black Leaf failed to prevent infestation of a character shown in Fig. 6 from taking place.

In starting in upon a control program the grower must first decide whether his trees are worth the expense involved. It is very questionable whether low yielding, badly diseased trees should be given attention other than by completely removing them in order that a healthy tree may be started in their place. As a reset in a badly diseased apple orchard, the Delicious variety offers more promise in the Hood River district than other good sorts, because of its greater resistance to the disease.

The method of attack here tentatively recommended includes, first, the use of surgery (Fig. 2) in cleaning up the old established cankers; second, subsequent annual painting; and third, the use along with these measures of a contact aphis spray such as Black Leaf 40. This should be used at the rate of 1-1000 to which is added casein spreader in the amount of two pounds to each 100 gallons of spray.

It is not at present feasible to attempt complete canker control on account of the high costs and unquestioned impossibility of keeping all parts of a tree free from the disease even though it is entirely cleaned up at the time control work is started. The control work should therefore center around the protection and prevention of further advance of the disease in the framework of the tree (Fig. 3). With healthy framework and scaffold branches fruitfulness can be maintained through renewal of fruiting wood as the smaller diseased branches are removed. As a rule, the disease is not as destructive in the smaller branches as it is in the lower portions of the tree. In pruning, vigorous, well-placed shoots should be left to take the place of larger diseased branches as shown in Fig. 11. Young vigorous wood growth of this character is much less susceptible to canker infection than old wood. Renewal of the top can therefore be accomplished if the advance of the fungus is checked in the framework of the tree.

Cutting out of the diseased areas is done preferably during July and August; this operation to be followed in two or three weeks—or before aphis start to work upon the new forming callus—with an application of a

tightly adhering, elastic tree paint similar to the Hood River tree paint. A thick covering should be applied with a brush. The thickness of application is important in that the thicker the coating, the longer it will serve as a barrier to the aphid. The delay in applying the paint suggested above is of importance since the period of protection is thereby extended much longer into the fall, a period during which time aphid activity is often most

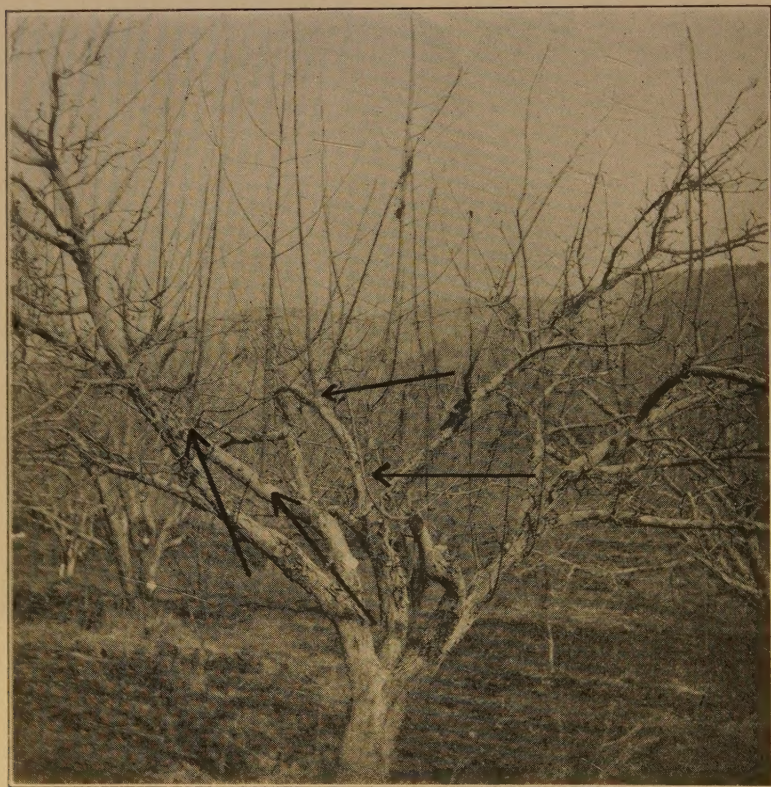


Fig. 11. Top renewal can be accomplished by leaving well-placed shoots at pruning time. Fruitfulness can be maintained by growing new wood when necessary. Perennial canker is less active on new than on old wood. Arrows point to new top.

extensive. The painting must be thoroughly and carefully done. As has been shown previously, incomplete coverings are worse than no coverings at all because of the actual protection which may be offered the aphid as a result of careless work.

The surgical work should also be done thoroughly and carefully. A clean-cut margin (Fig. 4: C) is extremely important. Ragged cuts leave places under which the aphid readily establish themselves. A strong budding knife and scraper have been found as good as any instruments for this type of work. A keen edge should be maintained on these tools at all times. The scraper can be used to remove the dead bark about the canker. This is

followed by use of the knife in cutting the margin. This cut should be made into sound, green tissue but should not be made further back from the dead area than is absolutely necessary in order that the resulting wound be kept as small as possible. Too much emphasis can not be placed upon doing careful, thorough work as upon this operation depends much of the success of future control work.

Growers should keep in touch with the work being conducted by State and Federal workers in the Pacific Northwest. At Hood River the Bureau of Plant Industry, United States Department of Agriculture, has established a laboratory in charge of Dr. J. S. Cooley. This office is devoting full time to the perennial canker problem. Pathologists in British Columbia and in the State of Washington are studying the problem. As a result of the activity of these various agencies, and the accumulation of knowledge that will follow, improvements in methods of control outlined in this bulletin will doubtless soon follow.

